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A WAKE CALL TO SEEING THE POTENTIALS OF AUTONOMOUS VEHICLES IN REVOLUTIONIZING INTELLIGENT TRANSPORTATION SYSTEMS IN NIGERIA: A MIXED-METHOD APPROACH

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ABSTRACT

The adoption of autonomous vehicle (AVs) has sparked considerable interest across diverse industries, including public transportation, underground mining, and agriculture sectors. The autonomous vehicle is about to hit the mass-market. The question is not about when it will happen but in which conditions, under which form or who will be the first autonomous vehicle manufacturer to release an efficient and reliable final product in Nigeria. By now, the equation has not been solved, due to the high price of the technologies needed, the lack of solutions to provide a reliable network, and the necessity to change conventions established before now in terms of responsibility of drivers. Nevertheless, the autonomous vehicle is not only an evolution of a previous product, which is able to evaluate and to progressively transform into a self-driven vehicle. This innovation is one step further and is challenging everything that had been established until now in terms of objective criteria expected from a vehicle. This is why it was called a disruptive innovation, or even a revolution, in the sense that it has the power to totally change the way we interact with our everyday transportation system. To enter into the market, this technology, will have to overcome some challenges, on the technological side but also on the psychological side of his future clients. Therefore, an heterogeneous method approach was employed, hybridizing quantitative data from surveys of approximately 2000 randomly selected individuals and qualitative insights from in-depth interviews with policymakers, traffic engineers, and industry representatives. The quantitative analysis revealed high levels of perceived usefulness (78.8%), positive attitudes (87.78%), and expected benefits (86.09%) among respondents, indicating optimism about AVs' potential to improve traffic efficiency and safety. However, concerns about technical and technological reliability, cybersecurity, and the cost of infrastructure upgrades persist.

Keywords: Groundwater Quality, Heavy Metals, Physicochemical Analysis, Agricultural run-off

INTRODUCTION

A large number of evolutions changed the characteristics of the mass-market vehicles since the first mass-produced vehicle (Ford et al., 1908). Before now, owning and having a car was a luxury. Nowadays, it became mainstream, and the automotive industry is following several trends that are daily shaping it into something desiring – improving, for example, safety, efficiency, connectivity. Among these trends, there is one trend which stands out as having the potential to be a game changer for urban traffic systems (Wyman et al., 2007): the Autonomous Vehicle (AV) Technology. A technology that every main actor is trying to develop as fast as possible, in order to build cars that will, in a more or less distant future, be able to drive themselves (Boston Consulting Group et al., 2016).

To do so, the AVs use a set of radars, cameras, GPS, motion and ultrasonic location sensors, accelerators, and of course computers to manage the data, the operations and the decision taking. An AV is a vehicle capable of sensing its environment and navigating without any human input. The AV thus have control systems capable of analysing all this data to go from a point A to a point B while distinguishing the different cars on the road and while managing the unexpected to happen.

The technology is everyday improving and step-by-step, the customers will get used to its benefits. The first indicators are the options available while buying a new premium car: indeed, driver assistance systems are starting to become mainstream on the market. Auto parking, lane warning, intelligent cruise control, emergency braking, are technologies that are started to get generalized, still in option but without any hesitation in serial in a few years. At first sight, we could think that these driver assistance systems will evolve gradually into fully AVs, but that's one of the misconceptions associated with AVs. The approach and the development of assistance systems that operate for a few seconds has nothing to do with the development of a technology that allows a system to make a car drive itself continuously for hours.

Who will be the first city in Nigeria to be fully equipped with AVs, or who will be the first Original Equipment Manufacturer (OEM) to put up on the market the first reliable AV in Nigeria. Then, some strategic questions have to be answered by the traditional players of the automotive industry: of course, OEMs have an important role to play, but the suppliers have a heavier weight we could think on a first thought, and technology providers like Google for example entered the game. The patriarchs of the industry (Volkswagen group, General Motors, Toyota…) are getting "tickled" by new-comers like Tesla, most advanced OEM in the development of AV and electric cars. Moreover, they are integrating vertically, developing their own self-driving system and providing their own batteries.

The aim of this research is to contribute an analytical framework of the dark side of innovation, technology diffusion, technical change in mature industries, related to the specific case study of the AV technology. The objective is to provide arguments to state the fact that some technological innovation has different aspects which have direct effects on employment, industry, environment, people behaviour, and that the Autonomous Vehicle technology is one of them. The research will challenge the decisions taken by the leader automotive groups in Nigeria and West Africa at large and to make a state of the art of this innovation which will obviously

throw lights on its huge positive attributes, some negative aspects that can't be avoided

Concepts of AV as being a Promising Creativity and Innovation

The concept of the AV is an innovation that could be compared to any other innovation concept: Adeney (1994) mentions the example of the knife to prove his point about the dark side of every new technology on the market. He mentions the fact that "a car may be used to rush a sick child to the hospital, or it may be used as a weapon to run over an enemy". This example of double standards is a relevant argument to prove that an innovation is not either black or white: we need to contrast the attributes of an innovation in order to define its positive or negative aspects. McLaren (1993), also mentions the dark side of creativity, meaning "the harm that scientific and technological creativity can do.

As a matter of fact, "Science cannot claim moral neutrality, much less moral indifference" (Snow, 1961). When an innovative technology arrives on the market, especially when this innovation is coming from a large industrial group, it has only one final purpose: create benefits. Whatever the way it is presented, the communication strategy that the company/group chose to apply, when an entity decides to invest money in the development of a technology, of a product, of a process, especially an innovative one, the objective is to create value that could deliver profits then benefits. In the meantime, creativity is well-received by the global customer market. Creativity and Innovation are correlated to efficiency and effectiveness, Tsanoff (1949) goes even further and says "What is this creative power of mind? Excellence so transcendent cannot be due to merely human powers; some divine principle speaks in the sage or see of poet". Plato (1952) even mentions it as a "divine influence".

As mentioned by McLaren (1993), the "concern for the negative impact of a new technology is not a new phenomenon". The industrial revolution that occurred during the 18th and 19th century that was made possible by the creativity of industrialists, was pointed by literary figures such as Coleridge or Victor Hugo for its devastating effects on domestic life among the poor and working classes.

Contrasts and Impacts of AV as a Worthy Innovation

Every innovation has a technical, technological side, but relies on an economical side, without which it couldn't work. Indeed, "rapid technological economic growth is an effective way to create wealth, such growth primarily benefits a small elite" (Adeney, 1994). That means that some innovations are not improving everybody's life but only a defined group of individuals, and that it increases the gap between the different segments of society. "Technology often seems to benefit the few at the expense of the many".

Some innovations have good sides but include the risk of having devastating bad sides – there is no better example than the nuclear power technology. This technology permits millions of people to have access to electricity, but its civil use includes the possibilities that we all know, not to mention the disaster that occurred in Fukushima in 2011 or, even worse, Tchernobyl in 1986.

An innovation also has an impact on our everyday's way of behaving with other people for example, even if we are convinced of the importance of this new product in improving our day-by-day routine. How many times did we hear from the persons that are not really into new technologies, when a new product entered the market, that they will continue to live their lives without it and that they don't want to be part of it? The smartphone is a really good way to illustrate this fact. With yearly sales of 1433 million in 2015, this is a good example of an innovation that took a lot of space in our lives. Did it improve our life? Obviously yes, since we can now have access to a whole world of information, culture, directly in our pocket. Did it increase our knowledge, our will to culture ourselves, read books or encyclopedia? Probably not, because even driven with good intentions, innovation and new technologies can sometimes become a distraction and the humankind is able to find a way to turn a genius invention into something worthless, or at least use it a different way that it was meant to be used at first glance.

Control and Limits of AV as a Worthy Innovation

Then comes the question of the control of innovation, and its limits. First, not every organization has the capacity to invest in large scale technologies. Only large companies or governmental institutions have the resources needed to invest in expensive Research and Development. The difference is that governmental institutions are public institutions, which must follow international or regional rules, while on the other hand, companies' innovations are in private hands. Capitalism claims it is safer, while Socialism prefers to see such power monopolized by the state (Ardenay, 1994). When companies start to have the investment capacity of large institutions, boundaries and rules should be established. But how a governmental organization could be able to have the level of expertise of a company which is pioneer in a specific topic? Do even companies have control on the innovation they create? Adeney (1994, p. 23) claims that "The power of technology must pass from the control of tiny institutional elites". As a matter of fact, institutions that control technology are motivated by power, profit, and to do so they are looking for competitive bias, new ideas, and new products. In order to stay competitive on a specific market, some companies must do choices, take decisions, and under, they could do mistakes and take the wrong path. Volkswagen group, to gain competition for the most efficient diesel mid-engine, took the responsibility to include an adaptive software in the on-board computer that could adapt to test procedures, while competitors took the decision to invest in expensive hardware solutions. Unfortunately detected by NHTSA (National Highway Traffic Safety Administration) modules, this software could cost Volkswagen more than $34 billion according to the last estimations from Forbes (2015).

This is one more proof, if needed, that within a competitive industry, taking risks is central and even for a large group like Volkswagen, evaluating the consequences of a decision and managing the risk is central. In the worst-case scenario, Volkswagen could lose customer faith, and then the sales volume could go down, carrying with it the production volumes… which directly impact employment. We will address later the topic of employment in the negative aspects of innovation.

MATERIALS AND METHODS

This study deployed a systematic literature review (SLR) methodology in accordance with accepted standards (Abel et al., 2025). One kind of literature review that compiles and evaluates a variety of research projects or publications in a specific field is called a systematic analysis.

The following inquiries are the focus of the study:

i. RQ1: According to state-of-the-art autonomous vehicle (AV) systems what is the perceptions of the Nigerian people on its adoption in the country

ii. RQ2: Which Scenario Analysis for Autonomous Vehicle Development and Deployment are the Country Nigeria need to looked at?
iii. RQ3: What is the main implementation, and adoption issues that the country specifically need to addressed?

To address each study issue, a comprehensive systematic literature review (SLR) was conducted using relevant scientific publications were located through searches in Scopus-indexed databases, including Frontiers, MDPI, Springer, ResearchGate, SAGE, Elsevier, Google scholar. The selection criteria for these publications were based on their relevance to the topic and their recency, focusing on journal publications and conference papers from the past five years. Among the key themes explored in these studies are the public's perceptions and acceptance of AVs, as well as their potential impact on transportation systems. For example, (Fonzone et al., 2024) in a study on autonomous buses (ABs) in Scotland pointed out five key factors exposure to AVs, system assessments, travel behaviours, personality traits, and demographic profiles that influence vehicles use and willingness to adopt automation. Another work in Singapore using the Unified Theory of Acceptance and Use of Technology (UTAUT2) exposed that interaction quality, societal influence, and performance expectancy drive public acceptance, emphasizing the role of consumer-centric strategies (Koh et al., 2023). Further, research on autonomous vehicles by Rahim et al. (2023), highlights the importance of perceived trust, safety, and usefulness in early adoption, suggesting that public education and safety assurances are critical to building confidence in such technologies. This ensured that the literature review was grounded in the most current and pertinent research available

Research and Methodological Approach

It is very important to specify that the objective is not to prove a point which would make this technology look bad for the humankind, environment, and industry. Nevertheless, the purpose will be to clarify the situation on several topics related to this novelty, and to replace into its context, the popularity, passion, craze that it aroused

Here is a graphical representation (Figure 1) of the conceptual framework which could be used to explore the field in the context of a disruptive innovation within a mature industry. The AV could be described this way.

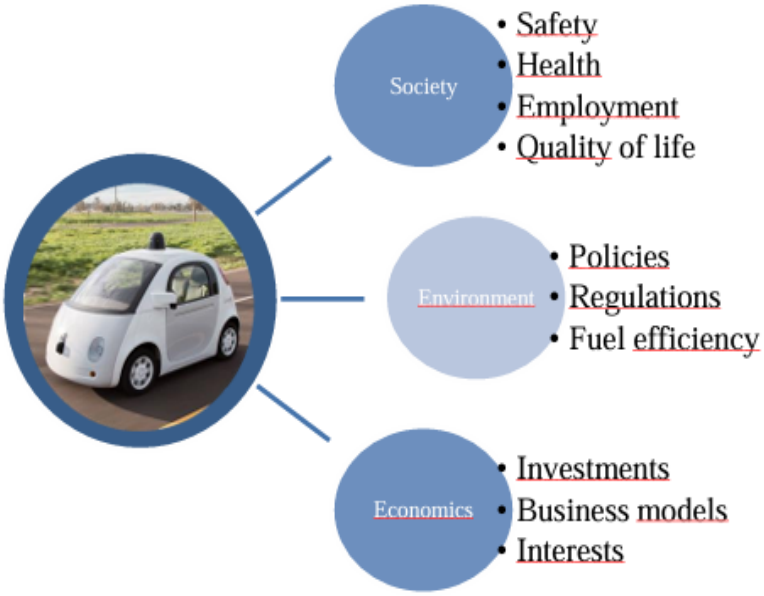

Figure 1: Conceptual Framework of the Avs

The data gathered in this research is mainly based on qualitative data, the information coming from questionnaires served to 2000 people which comprised of aged people, young people and teenagers and the interviews with experts in Innoson Vehicle Manufacturing Co. Ltd in Nnewi, Anambra State, Nigeria was conducted in relation to this research and what could be found in specialized medias, press and on the internet. Some quantitative data were extracted from surveys made by professional interviewers' reports from market and technical analysists.

Therefore, the research reasoning is mainly inductive, in the fact that from qualitative data are deducted specific observations allowing to make broad generalizations. The inductive reasoning has its place in the scientific method according to Bradford et al, (2015); scientists "use it to form hypothesis and theories".

Interviews and Questionnaires

In order to provide detailed and personalized information, in relation with the fact that for example companies are only communicating while using saleable and marketable arguments, 4 sets of interviews were conducted. Those interviews allowed to take in consideration some problems that are sometimes not addressed by the regular articles because too specific or irrelevant. These interviews provided strict and precise information from different perspectives, improving the knowledge and understanding of the challenges from the marketing view, software development view, infrastructure and regulation's view. The 5 individuals interviewed were all from the industry but occupied significantly different positions, which happened to be truly interesting because they were not always sharing their point of view regarding the direction this technology was going, and which impacts it would have in the future. It is relevant to

remind that their points of views were of course subjective and driven by their environment. Here, are come some of the questions asked during the interview and sample of the questionnaire used are shown in the appendix A

i. Which problems will the Autonomous Vehicle, in its final and optimized version, will be able to solve?
ii. Which scenarios are possible to your opinion?
iii. Do you think that it is necessary for car manufacturers to change their business models with the entry on the market of the Autonomous vehicle? If yes, why, and how?
iv. To your opinion, what could be the impact of the Autonomous Vehicle on the automotive sector? In what extent could it have an impact on society in a general way?
v. What is your opinion regarding the newcomers on the automotive market, pretending to revolutionize our travel habits, such as Google or Tesla? Their approaches are different and they are feared by the historical car manufacturers, should we take them seriously? If yes, why?
vi. When do you think the technology will be ready for the mass-market, and what could be the obstacles to overcome?
vii. What are the most important requirements, the minimum viable product that the Autonomous Vehicle should include?

RESULTS AND DISCUSSION

Nigerian Context for AV Systems

Nigeria, like most of the continent of Africa, is currently not technologically advanced and it has no AVs in testing or in use. Thus, short- and long-term training needs to be provided by relevant government bodies in order to familiarize Nigerian society with the AV concept. A problem is that Nigeria is a very rich-income country and its road network, vehicle density, and vehicle systems are all in their average state. A much larger road network would be required to enable the introduction of AVs in Nigeria, but there are a number of factors that might make a viable market for this technology. These include a huge and increasing population, a rapidly expanding economy, and an innovative administration. Furthermore, inadequate infrastructure for conventional vehicles may make autonomous vehicles more appealing than ordinary automobiles. The main hurdles that need to be overcome are road conditions and traffic patterns, as AVs must be capable of dealing with the country's peculiar driving circumstances, such as dirt roads, aggressive driving, and unpredictable traffic. Nigerians should become more and more interested in AVs in spite of these obstacles. The government needs to invest in research and development, and some private companies are to work on developing AVs for the Nigerian market (Debebe et al., 2022)

Road Infrastructure Conditions in Nigeria

Nigeria has a rather average road infrastructure in some of her capitals. The country has a massive road network, but many of its roads are in poor condition and pose multiple safety risks from potholes, unmarked obstructions, and a lack of safety barriers. The Nigerian government must invest in road infrastructure improvements, so as for progress to take place in the implementation and adoption of AVs. In the interim, driverless cars will need to be able to cope with Nigeria's poor road conditions in some of her state capitals like capital in Lagos State, capital in River State, capital in Enugu State, capital in Akwa Ibom State and the federal capital territory. Specific Road Infrastructure Problems in Nigerian

i. Condition of road surfaces (Alonso et al., 2022): The state of Nigerian road surfaces varies greatly. Some roads are in decent condition, while others have potholes and cracks.
ii. Road markings: On Nigerian roads, road markings are frequently non-existent or fading. Drivers may find it difficult to see lanes and make turns because of this.
iii. Signage: On Nigerian highways, signage is sometimes non-existent or badly maintained. Drivers may find it difficult to manoeuvre and avoid hazards because of this.
iv. Safety features: On Nigerian highways, safety elements such as safety barriers and rumble strips are uncommon. This can increase the likelihood of an accident occurring.

Despite these hurdles, there is growing confidence that self-driving cars have the potential to enhance Nigerian transportation by alleviating traffic congestion, increasing road safety, and expanding mobility alternatives for individuals with impairments. On the other hand, establishing more physical infrastructure would reduce urban land availability for houses and businesses, fragment and damage the environment and ecosystems, decrease biodiversity, and so on. This creates a risk of impacts on natural rivers, increasing floods and runoff, deteriorating aquifers, and increasing water demand.

Societal Perceptions of AV Systems in Nigeria

Perceptions and attitudes of Nigerian society to AVs were captured in questionnaire-based interviews with approximately 2000 individuals as emphasised by science daily, (2024) revealing both enthusiasm and concerns. Challenges such as limited infrastructure and public skepticism mirror global trends, where societal factors like perceived safety and enjoyment strongly influence adoption. Broader acceptance studies underscore the importance of targeted education and outreached to build public trust, providing valuable insights for tailoring policies in Nigeria. By addressing both societal and infrastructural limitations, the findings can guide the development of strategies for AV integration in similar contexts. Their responses are shown in Table 1, while the full questionnaire can be found in Appendix A of this article Table 1. Responses obtained in questionnaire-based interviews(N=2000) on perceptions and attitudes to autonomous vehicle (AV)systems. All interviewees were located in Anambra State, Enugu State, Delta State, Lagos State just to mention but a few and in both rural and urban areas.

Table 1: Percentage of Respondents in Different Socio-demographic from the Study Locations

Topic Areas Used	Statements Obtained	Percentage of Respondents in Different Socio-demographic					
		Male		Female		Status	
		Agree	Disagree	Agree	Disagree	Work	Habitat
Perceived ease of use	Learning how to use Avs would be simpler for me.	29.64%	37.3%	5.76%	27.27%	37% unemployed 63% employed.	54% urban. 46% rural.
	Using Avs would not need any mental effort	41.78%	29.17%	28.7%	0.33%		
	I found Avs straight forward to grasp.	49.83%	17.63%	5.42%	27.11%		
	It is simple to operate AVs.	36.12%	25.75%	26%	12.04%		
Perceived usefulness	My driving would be more comfortable if I used AVs.	52.91%	14.26%	28.46%	4.35%	37% unemployed 63% employed	
	Transporting people by Avs would be beneficial.	53.21%	12.85%	21.42%	12.5%		
	Avs would make my driving easier.	53.21%	13.35%	27.4%	6.88%		
Attitude	Using Avs is a wise idea	63.97%	2.49%	28.28%	5.25%		
	Using Avs is a good idea	63.97%	2.69%	28.96%	4.37%		
	Using Avs is a meaningful venture	60.25%	6.77%	25.59%	7.38%		
	Using Avs is an advantageous venture	58.14%	8.58%	21.95%	11.33%		
Perceived danger	What would worry me would be, technical and system malfunctions.	All considered all these a high risk					
	What would worry me would be, cyber-attacks (hacks).						
	What would worry me would be, high initial price.						
	What would worry me would be, whether it morally correct and ethical okay.						
	What would worry me would be, my private information would be disclosed.						
	What would worry me would be, users' or owners' legal responsibility.						
	What would worry me would be transportation sector jobs would decline as a result of AVs.						
Intention	If Avs are available in the future, I plan to use one	24.24%	No response	12.88%	62.87%		
	If Avs are available in the future, I plan to buy one	10.8%	No response	14.7%	74.49%		
Benefit	Avs would increase, traffic safety.	59.16%	5.8%	26.19%	8.85%	37% unemployed. 63% employed.	
	Avs would increase, fuel efficiency	56.86%	9.03%	32.1%	2.0%		
	Avs would increase, the mobility of persons unable to drive (disabled and old).	64.85% 2.05% 26.67% 4.44%					
	Avs would reduce, vehicle emissions	60.72%	5.73%	25.91%	7.62%		
	Avs would reduce, transport cost.	52.16%	13.9%	27.82%	6.12%		
	Avs would reduce, traffic congestion	Unknown				Unknown	Unknown
	Avs would requires less land use.	Unknown				Unknown	Unknown

Perceptions of AV Systems among the Interviewees

Analysis of societal perceptions was based on interviews conducted by researchers. There are many difficulties with conducting research concerning AVs and societal readiness, and also concerning the impact of autonomous technology on developing countries by either providing functions or damaging existing resources. The results indicated that more training is needed in developing countries to improve awareness and perceptions Analysis of societal perceptions was based on interviews conducted by researchers. There are many difficulties with conducting research concerning AVs and societal readiness, and also concerning the impact of autonomous technology on developing countries by either providing functions or damaging existing resources. The results indicated that more training is needed in developing countries to improve awareness and perceptions of the system. Previous studies have shown that safety is a primary concern in regards to Avs (Useche et al., 2021; Alonso et al., 2022). Table 2 presents perceptions and rates of acceptance among respondents in this study.

Table 2: Rates of Acceptance of Autonomous Vehicle (AV) Systems and Perceived Impacts on Existing Infrastructure. Existing Infrastructure

S/N	Merits/Demerits	Percentage of Interviewees in Agreement/Disagreement	Remarks
1	Perceived Advantages		
	Perceived ease of use	55.82	All questions raised by interviewers were answered but to different degrees.
	Perceived usefulness	78.58	
	Attitude	87.78	
	Benefits	86.09	
2	Perceived risks Safety	99.9% viewed AVs as risky and would be afraid of using them.	

Overall, the results indicated that AVs will be very difficult to implement in Nigeria without comprehensive public information and training. Many interviewees were in favour of the system, but most were afraid of using it, see Table 2.

Salient Benefits of Autonomous Vehicle

Here, we have combined knowledge from the theoretical framework, the case study and the interviews were examined and analysed in order to create a state of the art of the technology involved in the development of the Autonomous Vehicle. It makes common sense to say that the purpose of innovation is to solve a problem. The AV happens to answer to a lot of problems and is providing efficient solutions to the society.

The concept of the autonomous vehicle, despite its complexity, opens up new innovative applications and presents customers, manufacturers, programmers' and the world at large with the following benefits. The societal benefits of autonomous vehicle are easily identifiable – decreased traffic congestion, improved road safety and reduced carbon emissions. But will the automotive market change immediately into a sharing economy or will it stay as an individual luxury? Could it turn the Automotive market and the way we are interacting with the transport systems more sustainable? Just by taking the time to think about it permits one to recognize that AVs represent a vital paradigm shift to the mobility ecosystem – not only a technological revolution, but a value chain transformation. They offer several benefits once deployed, but a large number of challenges need to be resolved to achieve this sustainable mobility ecosystem in the future**.**

i. ***Rapid Boost on Economy***: Africa and especially Nigeria market is a good example of what could be the impact of AVs on our everyday life. Let's start by providing some numbers: the automotive industry is a critical component of the Africa and especially Nigeria economy, with "7 million private sector jobs supported by auto manufacturers along-side with IT professionals, suppliers and dealers in African Continents" and in particular Nigeria (Center for Automotive Research, 2021). This also includes people employed by the Original Equipment Manufacturers (OEMs), in the automotive parts sector (including workers in the rubber, plastics, battery, aftermarket, and parts export sectors), and in the dealer network. Still according to this report, "Every vehicle manufacturer job creates almost 7 other jobs in industries across the economy". This is providing more than $500 billion in annual compensation and is accounting for approximately 5 percent of Gross Domestic Product (GDP).

ii. ***Improved Safety***: Safety is a multidimensional feature in the automotive domain, where human lives take the highest priority when it comes to driving. In the case of autonomous vehicles, one of the most important applications is safe driving for its occupants. Every year road accidents claim 1.3 million lives and 50 million serious injuries as stated by the Federal Road Safety Corps, Nigeria (ITF et al, 2021). According to the National Road Traffic Crash Data Management System (NRTCDMS) of Nigeria through the National Committee on Crash Information System (NACRIS), 93% of traffic accidents are caused by human errors. The updated report on these numbers was published in February 2021 (Jo and Sunwoo, 2021) and stated that 94% of accidents are caused by human errors. Human errors are caused by various factors, including distraction, aggressiveness, carelessness, intoxication, and disabilities. Furthermore, such errors also cost about U.S.$190 billion in health costs and damages caused by these accidents (Ramsey et al, 2021). Based on these alarming statistics, an alternative driving mechanism is essential to save lives. In light of the aforementioned fatalities' statistics with human-driven vehicles, an autonomous vehicle can be a safer alternative with a lower number of human drivers behind the wheel. Autonomous vehicles will at least eliminate the likelihood of human errors that account for 94% of traffic accidents. Another dimension of safety is the vehicle itself. The autonomous vehicle will be equipped with sophisticated technology to authenticate its legitimate users, thereby preventing thieves from stealing the vehicle. With high-tech sensors on-board, the autonomous vehicle can successfully recognize its rightful owner and in case of any unwanted situation, it sends the owner an alert. Although these features, at least

in part, are still available in current middle- and high-end vehicles, nonetheless, the degree of intelligence will improve significantly in future autonomous vehicles. Furthermore, an autonomous vehicle might not need a key to start like traditional vehicles. Autonomous vehicles could operate with biometrics such as fingerprints, a retina scan, voice recognition software, and/or synthetic telepathy. It is worth mentioning that current vehicles have a fingerprint-enabled door-lock system, but these vehicles operations have not matured enough yet to a level where biometrics can be used. Two important conditions must be fulfilled in order to achieve such success: i) the penetration rate of fully AVs must be high and ii) cooperative traffic management strategies must work adequately. Otherwise, the increase in the number of vehicle km travelled could offset to some extent the decrease in the number of accidents.

iii. ***Business Opportunities and Increasing Revenue****:* Mobility-as-a-Service (MaaS) and vehicle sharing are two of the promising applications made possible through autonomous vehicles without redundant human interactions. The MaaS paradigm (Kamau et al,2020) will save many transportation and logistics companies and other vehicle end-users resources, including money, time, space, and even human resources (such as drivers). Autonomous vehicles can be used as a resource instead of owning a vehicle, which will require not only a large sum of money upfront but also a driver and a space to park it. Furthermore, vehicle sharing is a popular application among consumers (end-users) today. However, with the emergence of autonomous vehicles, vehicle-pooling can become more efficient by utilizing autonomous vehicle resources more effectively. In the last couple of years, vehicle-pooling services have garnered much attention among daily commuters for various reasons, such as saving money and time in addition to the hassle of driving that would otherwise make the commute stressful. With traditional vehicle-pooling, there are still time constraints when picking up fellow commuters on the way. Furthermore, the cost shared by the commuters may also consider the driver's costs. By using autonomous vehicles for vehicle-pooling services, we can eliminate such costs. This change in perspective will not only create economic advantages, but also decrease air pollution caused by traffic situations in global and national metropolitan cities and major cities. It also creates enormous business opportunities and transforms the mindset of both consumers and service providers. Autonomous vehicles will also revolutionize taxi and rent-a vehicle business. Taxi service providers will no longer need drivers, thereby reducing costs and increasing their revenue. Similarly, rental vehicle companies will be able to streamline their business operations with a reduced workforce. Furthermore, such a paradigm shift will also benefit the software industry because of smart applications (such as vehicle sharing, taxi services, and rent-a-vehicle services) that are accessible through personal devices. In short, autonomous vehicles can help increase revenue and reduce labor costs.

iv. ***The Advancement and Promotion of Big Data Networks***

As a large set of systems connected between them (radars, infotainment, thermometers, and accelerometers), the AV will be the main tool for the development of a Big Data network. The main contributors will be the final users, but also the technology providers, since this type of data will be implemented in their systems, and this is where Google for example is willing to become a standard. Google's business model is the organization at an international scale of the information and to allow its access from any part of the world. Naturally, the access to this source of information is most of the time free but always comes with a source of revenue, which could be personalized marketing, ads, or the re-sell of information's of communications.

The strategy behind the Google Car development is to test the implementation of those numerous information into a database that will then be usable on a larger scale, directly implemented and in real-time updated within the software on which will rely the interaction of the AV with its environment. Added to the Google database, the information gathered by the AV have infinite applications, on the same scale as the browsing history of a regular internet navigator has on our daily use of the internet network. The trip between home and work for example will then be a totally new experience, thanks to the new features allowed by the exploitation of the information gathered by the on-board Google software. Thanks to the geo-localisation and to the numerous captors embedded in a connected and AV, the car computer could be able to detect your hungriness and to propose you a detour by a restaurant of your favorite food, based on your previous researches, and the source of revenue would be a commission on the menu.

General Notable Solutions of Autonomous Vehicle Development and Deployment to Nigerians and Africans

The customers, manufacturers, programmers' and the world at large will say thanks to the AV from what was aforementioned, at least from the final customer point of view.

Stated below are some key facts and trend indicators (UN World Urbanization Prospects) can help to have a glimpse of what the present market would be made of, if AV would be the specific subjects that is focused on:

i. Road accidents are the 8th leading cause of death globally (the seven first are diseases)
ii. 95% of road accidents are due to human error
iii. 2 times more delay hours due to congestion in traffic by 2050 without a clear change
iv. 6.3 billion urban dwellers accounting for 70% of population by 2050

By the solutions that the AV provide, associated with a relevant infrastructure, relevant and reliable technology, with positive feedbacks from the final customers, this forecast could be embellished. The Earth Institute at Columbia University also estimated that autonomous driving can improve fuel efficiency by over 50% in some circumstances in developed countries.

Some countries like China, Germany, Japan, India, America just to mention but a few had already key in to this technology by introducing the practical use of "Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communication and fully autonomous driving by 2030" (Roland-Berger, 2014) so Nigeria, Africa and her citizens should wake up and embrace it also.

Scenario Analysis for Autonomous Vehicle Development and Deployment:

Different scenarios are possible for the supposed expansion of AVs. Its development relies on these five main criteria

Technology Readiness and Availability

How much the technology is advanced, how many years it will take before a reliable version? Google is already doing more than 10.000 miles a week with its Google Car, totalizing yet more than 1 million miles in the streets of both Mountain View, California, and Kirkland, Washington. Until now, only one crash happened, in February 2016, proving firstly that the technology is not ready yet, but in the meantime, only one crash, at 3 km/h, after more than 1 million miles (Google website, 2017) is quiet encouraging. What is missing is the convergence of sensor-based technologies and connected-vehicle communications, according to a KPMG and CARgroup report from 2019. The perception of the global environment is central for the accuracy of an AV decision taking. Unfortunately, so far, the fusion of available sensors and artificial intelligence is not capable of seeing and understand the vehicle's surrounding as accurately as a human being can.

Cost, Customer Willingness to Pay and Perceived Value of the Innovation

The solutions needed in order to make this technology viable, reliable and practicable are for the moment, very costly. For example, creating a 360- degree view of the vehicle's environment requires a combination of sensors and radars, and it may cost more than customers are willing to pay. 360-degree systems are the minimum requirement and must be associated with Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) for an AV to be able to operate in a secured and accountable way. The problem is, such a system actually costs $70.000 dollars in the Google Car for example. (Christensen and Wyman, 2019)

Customer Innovation Acceptance

No timeline is mentioned here. Some analysists are talking about a full AV technology available in 2025, some are talking 2030, 2035. Whenever it will be, the customer acceptance will be what will determine the market entry, or not, of the AV. As for any new technology, legislations, behaviours, needs, willingness to pay and desire will be really different depending on the region of the globe and social class of people (Wyman, 2019; Hill and Maranger, 2020).

Infrastructure

As stated in (Cardinal, 2019), the AV will be a connected vehicle or will not be. To do so, an infrastructure will have to be created, associated with a legal basis. When we mention infrastructure, it's both on the hardware and software side. Will it be necessary to standardize? Those questions have to be answered by the authorities and will most probably differ from a country to another. The governments and regulatory bodies have to develop future state urban network that address the gradual increase in vehicle automation, network connectivity and data requirement of AVs; these vehicles are gathering 750 MB/sec of date while fully functioning, and the infrastructure must be ready to provide a full-time reliable connection to the network for V2V communication. In the meantime, the authorities will have to anticipate the evolution of the technology and impact their solution choice, thanks to independent research and analysis. The conclusions will determine the new urban infrastructure. On the other hand, the infrastructure will rely on the technologies available in the portfolio of telecom companies. More than just a requisite data transfer speed, the telecom companies will be responsible of data mining and privacy. (Schwab Klaus, 2020; Copper and Maranger, 2020).

Specific Legal Basis

We shouldn't forget that the AV is developed to answer to identified needs in the market. We already mentioned some requirements but the main purpose is to delegate the driving to the integrated computer of the AV. Thus, the question of the responsibility if anything not planned happen will have to be addressed by the legal structures and once again, they are different depending on the continent, the region, and the country where the AV is used. For example, in order to allow the Google car to drive itself on the US roads, some legislations had to be modified. The same problem occurred in Europe, where the central legislation in Brussels had to adapt the Vienna convention via an amendment to authorize an AV to drive on European roads. (Matheson, 2020; Kiss, 2019)

As we can see in table 3, there is a few more stages before having a fully AV for sale in the market according to the Federal Road Safety Corps, Nigeria (ITF et al., 2021) and (NHTSA, 2013). Going from a level to its next one doesn't only include technology evolution, but all the factors that we mentioned in the scenario analysis as well and if well informed consulting firms, researchers just like this one, expert begin educate and sensitize Nigerians, the players in the automobile industry and the government in the few years to come will be enjoying the autonomous vehicles benefits such as provision of a fast, secured, adaptable, reliable transport system in the country and continents.

Table 3: Avs Operations and Dominance Projection (NHTSA 2013)

Levels/Stages	Descriptions	Notes
Level 0: No automation	All tasks are performed by the driver.	This is the current state of art, available on some new vehicles.
Level 1: Driver Assistance	Stand-alone vehicle components such as Electronic Stability Program (E.S.P) or Automatic Braking are present.	This is the current state of art, available on some new vehicles.
Level 2: Partial Automation	Combined automated features such as steering / acceleration, i.e., lane-keeping and adaptive cruise control are present.	This is the current state of art, available on some new vehicles.
Coordinated platooning	A group of self-driving cars travels in a tight, synchronized, single-file convoy, with the lead vehicle controlling the speed, and followers adjusting automatically via V2V/V2I communication and	Currently technically feasible but requires vehicle to vehicle communications capability, and dedicated lanes to maximize safety and mobility benefits.

Levels/Stages	Descriptions	Notes
	control algorithms to maintain minimal, safe gaps.	
Level 3: Conditional Automation	The driver can fully cease control of some of the important function of the vehicle in certain conditions, but he / she must remain ready to take control of the vehicle at all times with advance notice.	Currently being tested. Google experimental cars have driven more than 1 million miles in self-drive mode under restricted conditions.
Level 4: High Automation	The vehicle can execute all the driving functions. The option to control the vehicle may or may not be there with the driver.	Requires more technological development.
Regulatory approval for automated driving on public roadways		Some states have started developing performance standards and regulations that AVs must meet to legally operate on public roads.
Level 5: Full Automation	The vehicle is able to perform all functions related to driving, under all situations and conditions.	Several companies predict commercial sales of "driverless cars" between 2018 and 2020, although their capabilities and prices are not yet specified.
AVs become a major portion of total vehicle sales		Will depend on performance, prices and consumer acceptance. New technologies usually require several years to build market acceptance.
AVs become a major portion of vehicle fleets		As the portion of new vehicles with autonomous driving capability increases, their portion of the total vehicle fleet will increase over a few decades.
Market saturation	.	Everybody who wants an AV has one
Universal		All vehicles operate autonomously.

Hinderances to Overcome before Successful Autonomous Vehicle Development and Deployment

The AV innovation still has a lot of obstacles to overcome. Few were mentioned in the Scenario Analysis, such as authorities and society acceptance, and the development of the technical side of the technology

i. Diametrical Opposition by the Industries
ii. Developers' capacity and the reaction of the market
iii. Evolution of the network, infrastructure, the too much reliability on the communication systems (internet, 4G-5G network, GPS)
iv. Development of infrastructure and its standardization
v. Fear of hacking and cyber security by the main players developer teams.
vi. Standardization of the industry
vii. The requirement of a legal framework and regulations
viii. High cost related to development and adoption of autonomous vehicles
ix. Decision-making in the event of emergency situations.

CONCLUSION

This research was to make a state of the art of the AV technology perspectives and its impact on society and automotive market. One of the oldest and most mature industries on this planet, employing 10 million people only on the globe market, is about to take a turn that some may call a revolution in Nigeria and Africa, which will change the way we use vehicles and most generally will change our relationship with transport in a general way and it will come with sacrifices as some other innovations do which are the obstacles to overcome, on the technical and societal perspectives. The trend toward car sharing should nonetheless make automotive OEMs consider reconceiving their mission, at least in part. While continuing to serve as manufacturers and distributors of personally owned vehicles, OEMs should also experiment with providing mobility services and devise new business models accordingly.

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APPENDIX A

Questionnaire used in interviews with local residents in Adama city and surrounding areas, and key workers The principal objective of this key

Informant study is to explore the extent to which autonomous vehicles can be implemented in Ethiopia and its implications in the future. The study is being performed purely for academic (research) purposes. All responses will be treated as confidential and cannot be traced back to the individuals who provided them.

RESPONDENT'S PROFILE

AGE: _____SEX: _____MARITAL STATUS_____
LEVEL OF EDUCATION: _____
WORK STATUS: EMPLOYED: _____, UNEMPLOYED: _____
STATE OF ORIGIN: _____
PLACE OF RESIDENCE: URBAN: _____, RURAL: _____

Thank you for your response. Please read the following statements carefully and indicate whether you agree, disagree, or do not know by making a tick (√) or cross (X) in the space provided

Topics	**Statements**	**Respondents' Feedback from Different Socio-demographic**			
		Agree	**Disagree**	**Concept less**	**Comment**
Perceived ease of use	Learning how to use Avs would be simpler for me.				
	Using Avs would not need any mental effort				
	I found Avs straightforward to grasp.				
	It's simple to operate AVs.				
Perceived usefulness	My driving would be more comfortable if I used AVs.				
	Transporting people by Avs would be beneficial.				
	Avs would make my driving easier.				
Attitude	Using Avs is a wise idea.				
	Using Avs is a good idea.				
	Using Avs is a meaningful idea.				
	Using Avs is advantageous				
Intention	If Avs are available in the future, I plan to use one				
	If Avs are available in the future, I plan to buy one				
Perceived danger	What would worry me would be, the technical and system malfunctions.				
	What would worry me would be, the Cyber-attacks (hacks).				
	What would worry me would be, the High initial price.				
	What would worry me would be, the Whether morally correct and ethical.				
	What would worry me would be my private information being disclosed.				
	What would worry me would be users' or owners' legal responsibility				
	What would worry me would be Transportation sector jobs would decline as a result of AVs.				
Benefit	Avs would increase traffic safety				
	Avs would increase fuel efficiency.				
	Avs would increase the mobility of persons unable to drive (disabled and old).				
	Avs would reduce vehicle emissions.				
	Avs would reduce transport cost.				
	Avs would reduce traffic congestion.				
	It requires less land use.				